DECODING STEM/STEAM

THE TOY ASSOCIATION STEM/STEAM
STRATEGIC LEADERSHIP COMMITTEE REPORT

the toy association™

INTRODUCTION

While the terms STEM (Science, Technology, Engineering & Mathematics), and more recently STEAM (Science, Technology, Engineering, Arts & Mathematics), have been growing in popularity, there is massive confusion when it comes to defining what exactly they mean. Specifically, a lot of toys nowadays are labeled as STEM/STEAM, yet there is no universally accepted system or even a uniform understanding of what this definition implies.

The Toy Association has committed to bringing more clarity to the STEM/STEAM concept, especially as it relates to toys and play. The first step was to assemble a committee of experts in the fields of science, technology, engineering, and math—as well as education—**to address the growing needs of both our membership and the public to better understand the STEM/STEAM movement.** They are thought leaders, researchers, educators, authors, and beyond.

This report is the first in a series of communications that The Toy Association STEM/STEAM Strategic Leadership Committee will share with the following constituents:

- **General public,** to help everyone **understand the meaning** of STEM/STEAM
- **Parents,** to help them **make better toy selections** for their children
- **Teachers,** to help **inspire young minds** about STEM/STEAM subjects
- **Toy manufacturers,** to help **develop better STEM/STEAM products**

We believe that this exercise will provide the above constituents with the information and support they need to encourage children to use toys and play to ***develop intrinsic motivation to explore STEAM concepts,*** which could ultimately grow into a desire to pursue formal studies or a career in STEM/STEAM. The Committee invites you to join them on this journey to understand and promote the skills needed for our children's future, our economy, and our world, with the belief that it can be fun along the way by incorporating play. All aboard, and full STEAM ahead!

THE TOY ASSOCIATION STEM/STEAM STRATEGIC LEADERSHIP COMMITTEE MEMBERS

Babette Allina is director of government and corporate relations at the Rhode Island School of Design (RISD). Since joining RISD in 2008, Babette Allina has combined her experience as an artist with her background in public policy to advance the national agenda for STEAM education by raising awareness of the power of art and design to transform education, research, and workforce development.

Karen Bartleson is president and CEO of IEEE (Institute of Electrical and Electronics Engineers), the world's largest technical professional organization. Karen has more than 35 years of experience in the semiconductor industry, specifically in electronic design automation.

Dr. Jo Boaler is a professor of mathematics education at Stanford University, and the co-founder of youcubed.org, a website that offers resources and ideas to inspire and excite students about math. She is the author of the first MOOC (massive open online course) on mathematics teaching and learning.

Dr. Knatokie Ford is founder and CEO of Fly Sci Enterprise, an education and media consulting organization focused on leveraging the power of storytelling to promote social change, particularly in STEM fields. She previously served as a senior policy advisor at the White House Office of Science and Technology Policy (OSTP) during the Obama Administration. In her role at the White House, Dr. Ford oversaw development and implementation of a national initiative, the "Image of STEM," which was designed to raise visibility and improve the image of STEM fields and careers in order to help promote diversity in the STEM workforce.

Janet Iwasa is a research assistant professor in the biochemistry department at the University of Utah. Her broad goal is to create accurate and compelling molecular and cellular visualizations that will support research, learning, and scientific communication. Janet's award-winning illustrations and animations have appeared in scientific journals including *Nature, Science and Cell,* as well as in *The New York Times.* Her work has also been featured on television and in museum exhibits.

Roger Malina is an astrophysicist, editor, and art science researcher. He co-directs the Art Sci Lab at the University of Texas at Dallas in the School of Art Technology and Emerging Communication. The lab works on problems that cannot be addressed unless artists and scientists work together. He is the editor of the Leonardo Publications at MITPress which document and advocate the work of artists who partner with scientists and engineers, or hybrid professionals whose work bridges art and science.

Rafael Núñez is professor of cognitive sciences at the University of California, San Diego, where he is the director of the Embodied Cognition Laboratory. He investigates cognition—especially conceptual systems and imagination—from the perspective of the embodied mind. His multidisciplinary approach uses methods such as psycholinguistic experiments, gesture studies, brain imaging, and field research with isolated indigenous groups.

Lucinda Presley integrates the arts, sciences, technology, engineering, math, and the humanities with creative/innovation thinking in school and out-of-school learning settings. As executive director of ICEE (Institute of Creativity Empowers Education) Success Foundation, she works with partners in Texas, nationally, and internationally, developing school and museum programming, writing curriculum, and training teachers. She is also the executive director of ICEE Success Foundation's museum, Curious. Additionally, she is chair and executive director of the Washington, DC-based Innovation Collaborative, a coalition of national arts, STEM, humanities, and higher education institutions.

NOTE: *full profiles can be found in the appendix.*

INITIAL FINDINGS

Initial input from the Committee has been organized into four segments: **Meaning, Myths, Messages,** and **Toys Take You There.** In the "Meaning" segment, background, history, and opinions on STEM/STEAM are explored. The "Myths" section exposes the misunderstandings surrounding STEM/STEAM. The "Messages" section is a synopsis of the key points expressed by the Committee members. Finally, the section, "Toys Take You There," connects findings drawn from this report to toys and play.

MEANING OF STEM & STEAM

Definition

STEM—Each letter of this acronym stands for the fields of science, technology, engineering, and math.

A simplified definition is:

> STEM is a curriculum based on the idea of educating students in four specific disciplines—science, technology, engineering, and mathematics.

According to the National Science Teachers Association, "Most educators know what STEM stands for, but how many really know what it means? A common definition is:

> STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy." (Tsupros, 2009)

Background

To better understand STEM/STEAM, look to both its origins and its purpose. STEM itself was born in the information age, christened by the National Science Foundation and fueled by our ever-expanding appetite for technology that is better, faster, and smarter than a minute ago. It grew out of two intertwined needs—a workplace that demands STEM skills and an educational system that can pipeline people into those positions.

An argument could be made that STEM is a national focus, a societal call to action, a series of government policies, an academic emphasis, and, because of these, a marketing hot-button. Words like educational curriculum, workplace readiness, and global economy/competitiveness all relate and interact with the implications of this term.

STEM can also find meaning in two other words—**profit** and **prophet**. The **profit** relates to the desire to prepare our children for the workplace by educating and providing the skills they need to succeed; thereby helping our nation and its citizens to globally compete and prosper.

The **prophet** part refers to the future and how to prepare the next generation for a rapidly evolving, unpredictable world. As futurist and globalization guru Thomas Friedman, author of "The World is Flat," predicts, *"Being really good at learning how to learn, …will be an enormous asset in an era of rapid change and innovation, when new jobs will be phased in and old ones phased out faster than ever."*

STEM skills undoubtedly are needed for our future, but what about the innovation Friedman refers to—where does that fit in?

Innovation

Critics of STEM claim it's a short-sighted effort to prioritize school curricula by overly focusing on science, technology, engineering, and mathematics, which are perceived as crucial for future job opportunities and the development of the economy—but at what cost?

For the U.S. to maintain its preeminence in STEM, it must produce 1 million more STEM professionals over the next decade. This would demand an increase of students getting STEM degrees by 34 percent annually.

(Report by the President's Council of Advisors on Science and Technology, February 7, 2012)

STEM curriculum, as a national focus, has taken the emphasis off academic subjects reflected in the humanities and liberal arts educational model (once the staple of higher education) that would help drive innovation. Some fear that these disciplines are being drowned out by the rallying call for more hard science.

Journalist and author Fareed Zakaria explains in his book, "In Defense of a Liberal Education," *"Around the world, the idea of a broad-based 'liberal' education is closely tied to the United States and its great universities and colleges. But in America itself, a liberal education is out of favor. In an age defined by technology and globalization, everyone is talking about skills-based learning. Politicians, businesspeople, and even many educators see it as the only way for the nation to stay competitive. They urge students to stop dreaming and start thinking practically about the skills they will need in the workplace. An open-ended exploration of knowledge is seen as a road to nowhere."*

However, former Apple CEO Steve Jobs reinforced the important role of liberal arts during his unveiling of a new edition of the iPad when he said: *"It's in Apple's DNA that technology alone is not enough—it's technology married with liberal arts, married with the humanities that yields us the result that makes our hearts sing."*

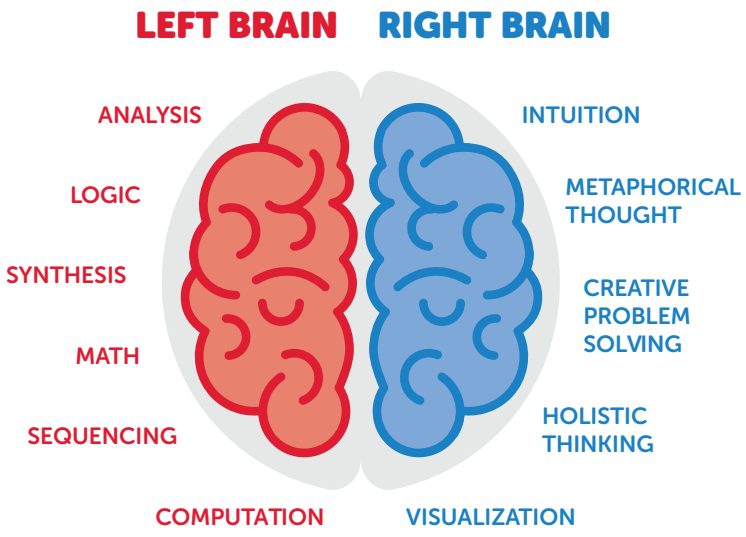
Facebook founder Mark Zuckerberg was a classic liberal arts student who also happened to be passionately interested in computers. He studied ancient Greek intensively in high school and majored in psychology while he attended college.

Adding the "A"

Based on a need for children to tap into their creative and imaginative skills to get innovation flowing, the "A" has made its way into the STEM acronym and cultural conversation. STEAM moved into focus and scientists, educators, and employers began to realize that something was missing in the STEM model of workforce preparedness—the whole second-part of the brain. This was the part of the mind where imagination and intuition resided and where creativity was often the path to finding another important "A"—answers!

The movement of STEM to STEAM had its champions including the Rhode Island School of Design (RISD), and their former president, John Maeda, who called for the integration of art, design and technology. Support from schools has followed. *THE Journal* magazine, the leading resource for administrative, technical, and academic technology leaders in K-12 education, has identified STEAM as one of their red-hot trends in education in a 2017 report. According to Dr. Rosemarie Truglio, SVP of education and research at Sesame Workshop in New York, "Incorporating the arts into our STEM curriculum was an exciting and natural addition, as Sesame Street has always used music, visual, and performing arts as tools to educate and entertain children.

Schools like Northwestern's McCormick School of Engineering shifted its curriculum by merging the analytical and technical components of engineering (left brain) with creativity, design, and divergent thinking (right brain). They call it "Whole Brain Thinking," and break down the different skills as:



The "A" in STEAM represents the artistic, creative, right side of the brain, known as the subconscious or unconscious mind. Sigmund Freud strove to establish the power and potential of this side of the brain when he asserted, *"The mind is like an iceberg; it floats with one-seventh of its bulk above the water."* To Freud, the size differential represented the power and the influence of our submerged subconscious right-brain abilities. Returning to Friedman's belief that we must teach the next generation to "learn how to learn," is it right that children's STEAM skill development rest solely on the shoulders of our educational system?

As Plato revealed,

"You can discover more about a person in an hour of play than in a year of conversation."

Perhaps equally true is that you can discover more about the world in an hour of play than any other way.

The Role of Play

Having referenced technology gurus like Steve Jobs and Mark Zuckerberg, let's turn to another leader in the global marketplace—Jack Ma, co-founder and executive chairman of China's Internet behemoth Alibaba. In the 2014 meeting of the Zhejiang Chamber of Commerce in Shanghai, he asserted that China's education system doesn't give students enough time or encouragement to just mess around, have fun, and experiment, when explaining how China has failed to produce innovators compared to the U.S.,

To this point, STEM/STEAM skill development has found a foothold in the toy industry and rightly so. Play is the easiest way to learn because the drive to play is built into all humans' DNA for a reason, combining left and right brain abilities (skills). Play teaches us about ourselves, others, and the world around us.

The clearest difference between education and play may be that play is fueled by intrinsic motivation that bubbles up from inner needs and desires; while education is mostly extrinsic, task oriented, heavily focused on memorization, and results in one right answer.

These ideas and more will be explored as The Toy Association STEM/STEAM Strategic Leadership Committee continues to delve into that rich intersection where confidence and competence in science, technology, engineering, math, and the arts are expanded through engaging with toys and play products.

"... play is not defined in terms of a single identifying characteristic, but in terms of a confluence of characteristics, all having to do with motivation or attitude and all of which can vary in degree."

Peter Gray. "Play as a Foundation for Hunter-Gatherer Social Existence," American Journal of PLAY (Spring 2009): 480.

MYTHS
COMMON MISCONCEPTIONS SURROUNDING STEM/STEAM

BORN TO CALCULATE. Our society has come to believe that you are either born with math skills or not. This misconception is probably fueled by a few children who are math savants when born and are then labeled "gifted." No one is born with a math brain and no one is born without one. Also learning math is ageless and we can wrap our minds around it at any age.

LIFE IS MATHLESS. Kids do not realize that the world around them has underpinnings of math everywhere. It touches their life in so many ways. The challenge is to make math relevant to kids' lives.

YOU NEED MATH FOR THAT. Kids do not need to be highly proficient in math to explore other areas of science, engineering, or technology. Students can fall in love with science or technology and still make amazing contributions without being a math expert.

"Many of the most successful scientists at work today are mathematically semi-literate."

-EO Wilson, biologist and author of "Letters to a Young Scientist"

MATH IS LIKE BRUSSEL SPROUTS. Some claim they do not like brussel sprouts yet have never tried them or who only had an overcooked, poorly-prepared version. Only if math has been served up to kids in a variety of interesting and engaging ways by teachers and parents who themselves are turned on by the magic and symmetry of math, can children then determine whether math is something they do or do not want to put on their plate.

MEMORIZATION NEEDED. Many young people are dissuaded from studying science, particularly biology and chemistry, because the first step in the learning process is a litany of things they need to memorize. Although kids need to know a common language depending on the field, memorization does not play a major role in job performance.

STUFF YOU DO IN SCHOOL, SAME AS THE JOB. Unfortunately, the attributes needed to be a successful student in STEM are not the same as those needed in an actual career. School demands problem solving, persistence, and exploring/discovering skills. However actually doing the science stuff requires these skills along with a different set of skills including observing, deep thinking, and curiosity/questioning.

STEM SHOULD BE TAUGHT ON TRACKS. Our current educational system is built on tracks that do not allow parallel growth in such fields as chemistry, physics, and biology. And yet all these disciplines often converge in the real-world workplace. These subjects can be taught in an integrated, related manner. Conversely, tracks can dissuade kids from continuing their interest in one field since track teaching demands dropping one subject and focusing exclusively on another.

PLAY IS JUST FOR KIDS. Wrong! Everyone can benefit from play and it continues to enrich our lives, our brain, and our relationships throughout our lifetime. Toys do not have to age out. We can find new ways to engage with toys and games throughout our lives, in fact they keep our bodies and minds young.

FOLLOW THE RULES. Games and toys can become so much more of a learning tool that relates to real life when we challenge the game play and change the rules. Any play object has the potential to be used in creative and innovative ways. Like the real world, norms need to be challenged to innovate.

Alexander Fleming made a game of science and used microbes to create bacterial paintings. The need for new colors required him to accumulate all kinds of cultures to accomplish this—including penicillin. According to the book, "Sparks of Genius," "No one knew what this mold meant at first, not even Fleming, because play has no direct or directing purpose outside of itself. Play is simply for the fun of it … Play breaks the rules of serious activity and established its own. Play is frivolous wandering according to the whims of curiosity and interest."

ONLY WHITE MEN NEED APPLY. Not any more—experts in STEAM come in all sizes, shapes, cultural backgrounds, and sexes. Yet we need to increase all areas of diversity including ideas and education.

"Diversity is the art of thinking independently together."

-Malcolm Forbes, founder of Forbes Magazine

LIBERAL ARTS DO NOT RELATE. There is a mistaken belief that skills and competencies delivered in a liberal arts education will not help in a STEM career. Defense of teaching a broader humanities-oriented curriculum has fueled the STEM to STEAM movement.

MATH WALL. When studying the sciences, a student might hit a math wall—a situation that challenges them beyond their skill set. The myth is that they should quit then, having used all their math abilities, and none is left. This is a fallacy. The wall is a mindset.

MESSAGES
KEY POINTS EXPRESSED BY THE COMMITTEE

ROLE MODELS, STEREOTYPING & CULTURE. Children need role models to imagine themselves as someday being scientists, engineers, technology experts or mathematicians; and to appreciate the contributions of artists, innovators, and inventors. Seeing is believing. In today's evolving workforce, STEM is underrepresented by women and minorities. Our children are highly influenced by their culture, movies, and media that has historically depicted STEM professionals as white males. Providing children with role models and cultural examples of diversity within the fields of STEM is an antidote to stereotyping. This mistaken mindset that STEM jobs/skills are only for a select few can be subconsciously triggered to self-sabotage individuals.

In 2015, women constituted only 28 percent of workers in these (science & engineering) occupations, although they accounted for half of the college-educated workforce overall.

(National Science Foundations, National Science Board, Science & Engineering Indicators, 2018.)

SEEING STEM AROUND THEM. Like oxygen, kids are not aware of all the elements of STEM/STEAM in their life. STEM is an abstract concept for them that is unconnected to their daily existence. The only STEM professionals they recognize and relate to are often their doctor or pet's veterinarian. Children need more exposure to professionals in the STEM community. Most kids have no idea what an engineer might look like or the types of jobs they perform—outside of a train conductor. Also, kids who have parents who are in STEM fields have a natural advantage and confidence to explore these professions.

FEAR OF THE "M" IS CONTAGIOUS. Math anxiety impacts 50 percent of the population and is also the major barrier to pursuing STEM careers. Teachers who are intimated by math influence young children along with parents. Children are not born with a fear of STEM/math, they learn it both through feedback and on a subconscious level. What teachers and parents believe really affects the students — especially women and people of color.

When parents are more math anxious, their children learn significantly less math over the school year and have more math anxiety by the school year's end—but only if math-anxious parents report providing frequent help with math homework.

(Psychological Science, 2015)

LOST THE "A" ALONG THE WAY. Historically, art played a big role in the work of scientists like Charles Darwin and Leonardo DaVinci and there is a need to bring it back into STEM and turning it into STEAM studies. We will never know if Einstein's love of playing the violin helped him come up with his brilliant theories, but what we are discovering is that the arts play a big role in empowering the solutions to scientific problems. The right brain's ability to be creative, visualize, think holistically, and imagine contributes incredibly to the areas of STEM and the "A" deserves a place in the acronym.

WORK THE HANDS, GROW THE BRAIN. Scientists have revealed and made the connection between working with our hands and fingers and mathematical abilities. Our finger and hand movements occur in the same areas of the brain as math which explains why musicians and math proficiency are often correlated (very much a STEAM exercise). Toys that encourage fine motor skills have the added benefit of growing the brain, especially the parietal cortex. Also, let kids count with their fingers, this helps them understand math kinetically.

MAKE IT OPEN ENDED. If we want to build scientists, artists, or successful individuals who can imagine things that have not yet been created, then we must allow kids to play with things that prompt the use of their individual imagination. This reflects the need for a play product to be used in multiple ways—there is no one way to play.

KEEP IT SIMPLE. Exploratory play with simple materials contribute to cognitive development. These experiences open up kids to learning and especially to creative and innovative thinking. Sometimes fewer items and the simpler they are, the more creative the products the students make. No step-by-step instructions…simply tell kids the outcome they need to achieve and their constraints. We need to tone down some of the bells and whistles on toys that can distract kids from focusing on one or two things that can in themselves be fascinating and engaging enough. More is not necessarily better.

TRANSFER SKILLS. When playing with toys, kids develop skills that can be transferred to their studies and success in STEAM such as observing, abstracting, recognizing and forming patterns, dimensional thinking, modeling, transforming and synthesizing, along with communicating and collaborating.

TOYS TAKE YOU THERE

Although it is obvious that some toys directly develop specific STEAM skills, there are also indirect skills and competencies related to STEAM that toys play a role in developing.

Here are the top 10 indirect benefits of toys and play as they relate to STEAM skills and attitudes:

1. Toys **establish intrinsic motivation which gets kids involved/passionate about STEAM subjects** and leads the way to developing a joyful, healthy relationship towards these disciplines.

2. Mistakes are OK—fail first, fail fast. Toys and play **teach kids how to fail and still have fun.** The handling of mistakes is an important mindset that contributes significantly to children's development of persistence/perseverance. Play is a risk-free zone.

3. Toys can **teach collaboration and social/emotional skills** which are greatly needed in the workplace. *New York Times* columnist and author Thomas Freidman in his keynote address at the Colorado STEM Summit shared his new term for these skill sets —STEMpathy.

4. Toys can **expand stereotype roles** (not just make them pink) and foster diversity of cultures and perspectives.

5. Toys can also **teach kids to take healthy risks in a playful environment** and transfer that confidence and courage to their future endeavors—including those in science, technology, engineering, math, presentations, performance, etc.

6. Toys can **promote hands-on work which helps the brain improve cognition** including math.

7. Toys can **encourage kids to explore their own talents** and develop their passion through play. This allows them to expand their interests and try out new things to help them identify what they like and want to pursue.

8. Toys can **help kids realize and relate STEAM skills to the world around them** making math and science relevant to things they experience every day such as cooking, running, and building.

9. Toys can **teach kids to problem solve, think deeply, and take their time**—in addition to many other transferable skill/competencies.

10. Toys can **integrate the arts into STEAM projects** by encouraging creativity, intuition, and imagination.

Toys and play have a tremendous potential to contribute to STEAM exploration by facilitating informal learning opportunities, which is perhaps best understood when contrasting against formal learning opportunities.

It should be noted that while all informal learning opportunities are not necessarily play, ALL play is an informal learning opportunity.

Also, while kids do not necessarily need toys to play, toys are tools to foster involvement, encourage engagement, create experiences, and instigate further exploration of STEAM skills.

FORMAL
LEARNING CHARACTERISTICS

1. Generally confined to school
2. Teacher led (hierarchical)
3. Attendance is mandatory
4. Defined curriculum
5. Focused on one subject at a time—track teaching
6. Controlled by standards
7. Verified by testing
8. Encourages conformity
9. Rule based
10. Limited to children of the same age & sometimes knowledge level (ranking)
11. Group can be diverse or lack diversity
12. Discourages free movement & spontaneous social interactions—somewhat desk bound
13. Discourages mistakes—one right answer—risk averse—CONVERGENT THINKING
14. Competitive in nature with rankings and test scores
15. Ridgely scheduled and timed
16. Advances at set pace as class progresses regardless of individual
17. Fueled by EXTRINSIC MOTIVATION
18. Feedback tends to come from instructor, tests or grades
19. Results tend to be on the cognitive level
20. Can cause stress

INFORMAL
LEARNING CHARACTERISTICS
(A.K.A. PLAY)

1. Unconfined—can take place at home, in nature, outdoors, playgrounds, or anywhere else
2. Child led
    a. Self-chosen
    b. Self-directed
    c. Can also be supported by parents/caregivers/teachers
3. Voluntary
4. Autonomous
5. Spontaneous
6. Interest vs. curriculum based
7. Can start before child reaches school age and continue throughout lifetime
8. Can be cross-generational—involving siblings, friends, and relatives of different ages and knowledge levels
9. Can explore multiple subjects at the same time
10. Rules can be adhered to or abandoned
11. Encourages trial & error
12. Allows for movement, social interactions, and body engagement
13. Fail free zone—mistakes are considered part of the game play—thrives on risk—DIVERGENT THINKING
14. Can be competitive or cooperative in nature
15. Not generally locked into a rigid schedule & embraces time to wonder, think, and ponder
16. Advances based on progress of individual(s)
17. Fueled by INTRINSIC MOTIVATION
18. Feedback tends to come from environment, fellow participants or observation
19. Results tend to be on the emotional, technical or practical level
20. Produces an active, alert, and non-stressed frame of mind

CONCLUSION

The primary goal of The Toy Association's STEM/STEAM Strategic Leadership Committee is to help toy manufacturers, parents, teachers, and the general public better understand the concept of STEAM and how toys and play can contribute to building STEAM skills in children. Beyond this specific goal, there is a potential bigger social outcome to this initiative. By encouraging and supporting informal learning opportunities (a.k.a. play) that explore STEAM, toy manufacturers, toy retailers, parents, and educators are helping to prepare children for formal STEAM studies and careers. As our society has an ever-increasing need for individuals in the fields of science, technology, engineering, the arts & math, this initiative could have a positive impact on workplace readiness by helping more children discover their interest in these subjects early on.

The Toy Association STEM/STEAM Strategic Leadership Committee will continue to address the growing needs of all constituents to better understand the STEM/STEAM movement. As a next step, the Committee will look more specifically at the unifying characteristics of STEAM toys to guide the efforts of toy manufacturers in developing products that facilitate STEAM discovery and learning.

APPENDIX

THE TOY ASSOCIATION STEM/STEAM STRATEGIC LEADERSHIP COMMITTEE—FULL MEMBER PROFILES

Babette Allina is director of government and corporate relations at the Rhode Island School of Design (RISD). Since joining in 2008, Babette Allina has combined her experience as an artist with her background in public policy to advance the national agenda for STEAM education by raising awareness of the power of art and design to transform education, research, and workforce development. Allina serves as RISD's primary liaison with governmental leaders at the Rhode Island State House and in the U.S. Congress, and with other external partners. She also works closely with students interested in issues of public policy, helping them learn to harness their creative abilities to enhance communication and connect with decision-makers. Prior to RISD, Allina focused on developing funding for large-scale life sciences research at the University of Rhode Island, working with such federal agencies as the National Science Foundation, Department of Defense, and Department of Energy. In her artwork, she explores the intersection of art and science—most recently by creating disorienting environments that address the devastating effects of Alzheimer's disease. Allina earned a Bachelor of Arts in politics and painting from Bennington College and a Master of Arts in political science from RISD.

As a child, I could get lost playing dress up with dolls and playing "war." I liked observing insects and catching salamanders. I grew up at the beach, so I spent a lot of time looking at the water. I enjoyed toys that let you make things—particularly if a transformation was involved such as "Fright Factory" type stuff with plastic molds and toys that lets you design cars or melting things like Shrinky Dinks.

Thought to share: "Tinkering," is at the heart of the ideation process, and the more "useless" the object you're working on, the better. Kids are generating their own identity out of what they are making—and working on creating their own story. Allowing them to develop their individual story instills children with the power to transform.

I wish I knew growing up that art fosters scientific success and research proves it.

One of my heroes is Neil deGrasse Tyson, an American astrophysicist, author, and science communicator. Since 1996, he has been the director of the Hayden Planetarium at the Frederick Phineas and Sandra Priest Rose Center for Earth and Space in New York City. Tyson is also a communicator and promoter of the sciences in contemporary culture through his appearances in movies and TV shows such as Cosmos: A Spacetime Odyssey and StarTalk.

Karen Bartleson is president and CEO of IEEE (Institute of Electrical and Electronics Engineers), the world's largest technical professional organization. Karen has more than 35 years of experience in the semiconductor industry, specifically in electronic design automation. Fascinated by math and science growing up, she found herself in a male-dominated field. With no regrets, she pursued a career in engineering to use her talents to help improve the global condition. Her current interests include internet governance, cyber-security, and cyber-privacy; global public policy; and ethics in technology. In 2003, Karen received the Marie R. Pistilli Women in Electronic Design Automation Achievement Award. She earned a Bachelor of Science in engineering science with a concentration in electronic engineering from California Polytechnic State University in 1980.

As a child, we used to play Batman, Robin, and Catwoman in our back yard all the time. I also loved playing with dinosaurs and Matchbox race cars and tracks for hours on end. I made all kinds of things with Play-Doh. I liked making molded things like wiggly bugs and figures using machines like Vac-U-Form. Easy Bake Oven was great, too!

Thought to share: In my opinion, certain types of play are actually practicing skills. For example, playing teacher helps develop one's communication skills, and building things out of LEGOs or construction sets help develop engineering skills. I also think that what children enjoy playing with might indicate where their talents lie.

Message for kids: I think we in STEM fields have a marketing problem. Children are exposed to all kinds of enticing careers—doctor, firefighter, athlete, chef, police officer—but there isn't enough emphasis on STEM. Think of all the TV programs that glamorize these careers. And what TV show does STEM get? "The Big Bang Theory." Ugh. Laughing at geeky, socially awkward people does not really inspire me to want to be one of them. (Sorry if you like the show.) I think the two biggest obstacles for kids to pursue STEM are lack of awareness about how really cool STEM is and traditionally gender-directed expectations for kids.

Heroes? People like Bill Gates, Mark Zuckerberg, and Elon Musk have become household names of successful STEM heroes. But I think we have a lot of work to do to publicize STEM heroines. People know the name of Marie Curie, but not many more. Many more women have fascinating and inspiring stories. There is a publication called "100 Women Leaders in STEM," that acknowledges role models of STEM leadership among women which is tackling this subject and published by STEMconnector®, a consortium of organizations committed to this issue.

Dr. Jo Boaler is a professor of mathematics education at Stanford University, and the co-founder of youcubed.org, a website that offers resources and ideas to inspire and excite students about math. She is the author of the first MOOC (massive open online course) on mathematics teaching and learning. Former roles have included being the Marie Curie Professor of Mathematics Education in England, a mathematics teacher in London, and a researcher at King's College, London. Her PhD won the national award for educational research in the United Kingdom. She is a fellow of the Royal Society of Arts; and the recipient of a National Science Foundation Early Career Award, a National Council of Supervisors of Mathematics Equity Award, and California Mathematics Council Mathematics Leadership award. She is the author of nine books, two TEDx talks, and numerous research articles. She was recently named one of the eight educators "changing the face of education" by the BBC. Her latest book is Mathematical Mindsets: Unleashing Students' Potential through Creative Math, Inspiring Messages and Innovative Teaching (2016), published by Wiley. She serves as an advisor to several Silicon Valley companies. She was an Aspen ideas speaker and a White House presenter on girls and STEM. Her work has been published in *The Times*, *The Telegraph*, *The Wall Street Journal*, and many other news outlets.

As a child, we didn't have much money for toys (neither of my parents went to college) and I enjoyed patterns and ordering so I made a huge collection of batteries! I was fascinated by their differences in size and color and I ordered and re-ordered them a lot. Now my family all tease me about my battery collection! I was also given a set of Cuisenaire rods that I loved and spent many hours with. (These are color rods of different length that are used as a hands-on way to explore and learn mathematics in visual, kinetic, and playful ways.)

Thought to share: Math anxiety impacts around 50 percent of the population. Teachers and students themselves should believe everyone can learn math at high levels. The most important message parents and teachers can convey to a student struggling is, "I believe in you."

Message for kids: The environment is filled with wonder and curiosity and classrooms should be a risk-taking, mistake-valuing environment. Math should be viewed as an unexplored puzzle that can be looked at and investigated in different ways, including visually, creatively, and collaboratively.

Heroes? Maryam Mirzakhani, my former Stanford friend and colleague, was the first woman to win the Fields medal in mathematics. Maryam passed away recently, at a young age, but will always be remembered for her visual, creative mathematical work that helped to solve mathematics problems that had never been solved and connect previously unconnected areas of mathematics. As a woman of color, who overcame barriers including her middle school teacher not thinking she was good at math, and who went on to be the most successful mathematician in the world, she is an inspiration to many.

Dr. Knatokie Ford is founder and CEO of Fly Sci Enterprise, an education and media consulting organization focused on leveraging the power of storytelling to promote social change, particularly in STEM fields. She previously served as a senior policy advisor at the White House Office of Science and Technology Policy (OSTP) during the Obama Administration. In her role at the White House, Dr. Ford oversaw development and implementation of a national initiative, the "Image of STEM," which was designed to raise visibility and improve the image of STEM fields and careers in order to help promote diversity in the STEM workforce. This effort is listed in the top 100 science and technology accomplishments of the Obama Administration. She previously served as an AAAS Science & Technology Policy Fellow at OSTP from 2012 to 2014 with the President's Council of Advisors on Science and Technology (PCAST) where she managed concurrent projects on education technology and improving the nation's health care system. Prior to working at OSTP, Dr. Ford was a postdoctoral research fellow at Beth Israel Deaconess Medical Center in Boston, MA. She also spent time in Los Angeles, CA, where she had the opportunity to work in the entertainment industry and serve as a middle school teacher in an underserved community in South Central Los Angeles. Dr. Ford completed her PhD in experimental pathology at Harvard University where she studied age-related macular degeneration and received a Bachelor of Science and Master of Science in chemistry/biological chemistry from Clark Atlanta University.

As a child, I used to play with Barbie dolls (individually and with friends) and would be in my own little world creating scenarios for the everyday lives of my Barbies. I made clothes and jewelry for my Barbies. I was also a bit of a "tomboy" and would play sports and video games with my brother who is a year and a day older than I am. I enjoyed outdoor play as well, and my father would often take me and my brother on fishing trips and to play basketball on weekends. My father treated my brother and I equally, so I never had a sense that there were things that I was not supposed to do because I was girl.

Thought to share: I don't think kids are born being intimidated by STEM…their environments condition them to embrace it or be afraid of it. Helping kids make direct connections between STEM and their everyday lives can make it friendlier and less abstract. Encouraging parents and helping them feel less intimidated by STEM is also important because parents play a critical role in influencing their children's interests and can unknowingly pass on their own fears of STEM subjects to their children.

I wish I knew growing up: I wish I had known more stories of underrepresented groups in STEM (women, minorities, and people with disabilities). I also wish I had been exposed to computer science as a child...it was not even on my radar and I would have loved to combine computing with my interest in biomedical science.

Hero? I love the fact that Katherine Johnson (NASA mathematician) had her story brought to life in the movie *Hidden Figures*. She made such critical contributions against unfathomable odds...she's a really an incredible woman.

Janet Iwasa is a research assistant professor in the biochemistry department at the University of Utah. Her broad goal is to create accurate and compelling molecular and cellular visualizations that will support research, learning, and scientific communication. Janet's award-winning illustrations and animations have appeared in scientific journals including *Nature, Science and Cell,* as well as in *The New York Times.* Her work has also been featured on television and in museum exhibits. Janet was named a 2017 TED senior fellow and recognized as one of the "100 Leading Global Thinkers" of 2014 by *Foreign Policy* magazine and one of the "100 Most Creative People" of 2012 by *Fast Company* magazine. As a postdoctoral fellow, she created a multimedia exhibit with Nobel Laureate Jack Szostak (Harvard University) and the Museum of Science, Boston, and later worked on biological visualizations as a faculty member at Harvard Medical School. She received her PhD from the University of California, San Francisco for her work on the actin cytoskeleton in the laboratory of Dyche Mullins and completed 3D animation training at the Gnomon School of Visual Effects later that same summer.

As a child, I did a lot of imaginative playing and role play with my friends. For example, my friends and I would often pretend we were veterinarians, with our stuffed animals as our patients. I would do a lot of crafting/drawing on my own and filled notebooks with drawings and stories. I was a pretty outdoorsy child and was fascinated with insects. At one point, I kept a box of crickets in my bedroom to hear them chirp at night. I also really enjoyed catching fireflies. Once I was a bit older, I liked to draw using my dad's computer. There was software called HyperCard that I loved to use to create choose-your-own-adventure type games.

Thought to share: Art and creativity play a big role in STEM fields. For example, in biology, art and research used to go hand-in-hand—biologists needed to draw/record their observations in order to share them with their peers. I think that connection is a lot less emphasized these days in the biological sciences, unfortunately, but visualization still plays an important role in research.

Message for kids: Biology isn't about memorizing a bunch of vocabulary words and facts from textbooks, although it can feel like that in school sometimes. Scientific practice is really about just wondering about how things work, and then coming up with a way of figuring out how to test those questions. Staying curious is the key to being a good scientist!

My heroes are some of the graduate students I have met who come from a variety of backgrounds, some of whom have faced an uphill battle to make it to where they are. I find their stories inspiring. Groups like SACNAS (Society for Advancement of Chicanos/Hispanics and Native Americans in Science) and Vanguard STEM are doing a great job in creating a community of supportive and diverse scientists.

Roger Malina is an astrophysicist, editor, and art science researcher. He co-directs the Art Sci Lab at the University of Texas at Dallas in the School of Art Technology and Emerging Communication. The lab works on problems that cannot be addressed unless artists and scientists work together. He is the editor of the Leonardo Publications at MITPress which document and advocate the work of artists who partner with scientists and engineers, or hybrid professionals whose work bridges art and science. He is collaborating with music professor Kathryn Evans, researcher Eun Ah Lee, and high school science teacher Jason Brogden to develop novel ways for people to interact with and understand data.

As a child I played with amateur science and astronomy stuff along with model rockets. I also collected insects and butterflies. My grandmother lived with us part of the time—she, my father, my brother, and I would play games all the time—cards, 42 dominos, etc.

Thought to share: The 'disciplines' such as science and engineering are relatively recent words in the history of ideas. In the last 10 years, under the leadership of John Maeda and the SEAD (Sciences, Engineering, Arts and Design) network, the term 'STEM to STEAM' has gained traction to indicate the importance of integrating arts, design, and humanities into STEM, both motivated by creativity/innovation research but also for problems that unavoidably bridge science and engineering and their social and societal context.

I wish I knew growing up: Working on hard problems can sometimes only be solved by combining STEM with the arts, design or humanities.

Heroes? Two of my heroes are authors of the book, "Spark of Genius: The Thirteen Thinking Tools of the World's Most Creative People," by Michigan State University professors Robert S. Root-Bernstein (psychology professor) and Michelle M. Root-Bernstein (history and creative writing professor). Having studied creativity for more than a decade, they have shared their findings. (Spoiler alert: 1 or the 13 thinking tools in Spark of Genius is play!)

Rafael Núñez is professor of cognitive sciences at the University of California, San Diego, where he is the director of the Embodied Cognition Laboratory. He grew up in Chile, obtained his doctoral degree in Switzerland, and completed his post-doctoral work in Stanford and Berkeley, CA. He investigates cognition—especially conceptual systems and imagination—from the perspective of the embodied mind. His multidisciplinary approach uses methods such as psycholinguistic experiments, gesture studies, brain imaging, and field research with isolated indigenous groups. His book, "Where Mathematics Comes From: How the Embodied Mind Brings Mathematics into Being," (with George Lakoff) presents a new theoretical framework for understanding the human nature of mathematics and its foundations. He is the founding co-director of the Fields Cognitive Science Network for empirical study of the nature of mathematics, based at the Fields Institute in Toronto, Canada.

As a child, I loved (and still do!) exploring nature outdoors, leaves, sea creatures, animal behavior, and playing tennis and riding my bike (and taking care of it). My dad had a good workshop and I made little simple objects in wood, plastic, and tin. I remember building a water ski also a wooden paddle racket.

Thought to share: Science and math should be taught as a human (collective) form of sense making—which is the process by which people give meaning to their experiences. Kids and students should understand the human saga behind these subjects. I myself have enjoyed trying to figure out what is the nature of mathematics and how we create it and pass it along to younger generations.

Message for kids: The curriculum in these areas of STEM tends to be highly normative, dogmatic, and arid, centered on "truths" about the world, and this alienates many students. There is little space for genuine inquiry and embodied sense-making, little explorations of the struggles and trials-and-errors involved in how the bodies of knowledge got to be the way they are now.

Heroes? Charles Darwin. His profound empirical and theoretical work stemmed from observations done outside the cozy and convenient world his society knew. That helped him challenge the conventional wisdom (about the nature of humans and their relationship with the rest of the living world, the nature of religion, the age of the Earth, etc.).

Lucinda Presley integrates the arts, sciences, technology, engineering, math, and the humanities with creative/innovation thinking in school and out-of-school learning settings. As executive director of ICEE (Institute of Creativity Empowers Education) Success Foundation, she works with partners in Texas, nationally, and internationally, developing school and museum programming, writing curriculum, and training teachers. She is also the executive director of ICEE Success Foundation's museum, Curious. Additionally, she is chair and executive director of the Washington, DC-based Innovation Collaborative, a coalition of national arts, STEM, humanities, and higher education institutions. With more than 25 years of experience in writing curriculum and developing STEAM programming for schools and museums, she has led STEAM education initiatives and teacher/artist training for a science museum, an art museum, and a national arts provider. She holds a master's degree in interdisciplinary studies. She has been an adjunct instructor of art at a community college for over 19 years, where she was recently named Adjunct Instructor of the Year.

As a child, I remember playing with dolls for hours on end…and lost track of time. I also loved to build with blocks, Tinker Toys, and snapping blocks. As a child, I loved to paint and that has continued into my adult life.

Thought to share: I believe that open-ended, hands-on exploration with simple materials contribute to cognitive development of children. In my work with creative thinking experts and neuroscientists, I have developed these experiences and am amazed at how it opens up kids to learning—especially to creative and innovative thinking. I've seen that the fewer items and the simpler they are, the more creative the products the students make are. No step-by-step instructions, simply tell them the outcome they need to achieve and their constraints, and watch amazing things happen!

I wish I knew growing up: The perceptions that STEM is for "smart" white males only and that it's for people whose families have money to send them to college are not true. Also, the way STEM is often presented is so standards-focused (passing the test) that all the fun is taken out of the exploration, inventing, and immersing in the science itself.

My hero is Congresswoman Suzanne Bonamici who founded and co-chairs the bipartisan Congressional STEAM Caucus.

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